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14. ABSTRACT

On 18 October 2011 the University of Redlands (Redlands) cooperated with US Army Engineer Research and Development Center, Construction Engineer Research Laboratory (ERDC-CERL) Center for the Advancement of Sustainability Innovations (CASI) to hold a one-day workshop at ERDC-CERL in Champaign, Illinois to review research in Spatial Decision Support (SDS), which has been defined as “the computational or informational assistance for making better informed decisions about problems with a geographic or spatial component.”

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Report Title

Spatial Decision Support Workshop 2011

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On 18 October 2011 the University of Redlands (Redlands) cooperated with US Army Engineer Research and Development Center, Construction Engineer Research Laboratory (ERDC-CERL) Center for the Advancement of Sustainability Innovations (CASI) to hold a one-day workshop at ERDC-CERL in Champaign, Illinois to review research in Spatial Decision Support (SDS), which has been defined as "the computational or informational assistance for making better informed decisions about problems with a geographic or spatial component."

CASI Director Bill Goran began the program with an overview of ERDC-CERL's past and ongoing SDS-related research. Redlands provided a summary of their research and case study projects. Invited participants presented summaries of their research initiatives. In the afternoon, participants engaged in a discussion to synthesize knowledge, and to formulate ideas for future collaboration and technology transfer for specific DoD application areas. The discussion covered a range of topics that emerged as focal points for future research: 1) Theory, Methods, and Best Practice; 2) Technologies; 3) Domain Application Areas; 4) Standardization; and 5) Education and Training.

Technical Report: Spatial Decision Support Workshop

Acknowledgement

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Abstract

On 18 October 2011 the University of Redlands (Redlands) cooperated with US Army Engineer Research and Development Center, Construction Engineer Research Laboratory (ERDC-CERL) Center for the Advancement of Sustainability Innovations (CASI) to hold a one-day workshop at ERDC-CERL in Champaign, Illinois to review research in Spatial Decision Support (SDS), which has been defined as "*the computational or informational assistance for making better informed decisions about problems with a geographic or spatial component*."[1]

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Background

The SDS Consortium defines spatial decision support as follows:

> *"Spatial decision support is the computational or informational assistance for making better informed decisions about problems with a geographic or spatial component. This support assists with the development, evaluation and selection of proper policies, plans, scenarios, projects, interventions, or solution strategies.*
>
> *Spatial decision making faces various decision complexities such as:*
>
> - *Spatial nature and temporal development of phenomena and processes;*
> - *Complex multi-dimensional and heterogeneous data describing decision situations;*
> - *Large or extremely large data sets that include data in numerical, map, image, text, and other forms;*
> - *Large number of available alternatives or a need to generate decision alternatives "on the fly" according to the changing situation;*
> - *Multiple participants with different and often conflicting interests;*
> - *Multiple categories of knowledge involved, including expert knowledge and layman knowledge."*

[1] http://www.spatial.redlands.edu/sds/ontology/?n=SDSSAbout:SDS

Spatial and location-based information is an integral part of DoD operations and installation management. Spatial decision support processes and systems combine GIS and other information technologies to provide a structured approach to problem solving, in which information is organized and presented to decision makers in a way that helps to promote better decisions. SDS serves as an analytical framework that organizes workflow process for decision-making and alternatives analysis.

The University of Redlands' Redlands Institute conducts applied Geographic Information Science research toward improving the quality of spatial decision processes for resource management. Army Research Office (ARO) grant funding to the University of Redlands has advanced our knowledge in Spatial Decision Support (SDS), the study and practice of which is relevant to Geographic Information Science (GIScience), Operations Research, Planning, Natural Resource Management, and other disciplines. Redlands is applying SDS to a variety of projects and problems facing DoD installations and operations, including recovery of endangered species (desert tortoise) in the Mojave Desert, management of non-native and invasive species (NIS) at Ft. Huachuca (AZ), and multi-criteria prioritization of infrastructure investments for the U.S. Army Corps of Engineers with the Institute for Water Resources (IWR).

One of the principal products of Redlands' research is the SDS Knowledge Portal (www.spatial.redlands.edu/sds), which was co-developed with the SDS Consortium (http://www.spatial.redlands.edu/sds/consortium). Under ARO funding, Redlands has convened a Consortium of international experts in SDS to codify collective expertise into an SDS ontology, hosted by the SDS Knowledge Portal. The SDS ontology provides a structured body of knowledge on essential concepts in the SDS field of study, their properties and interrelationships. The ontology-driven SDS Knowledge Portal contains over 800 concepts with natural language definition, plus formally defined logical relationships, about 100 methods, entries for 80 SDS tools and models, various data sources and case studies, and more than 600 literature references. A parallel GeoDesign Knowledge Portal offers similar resources for this emerging discipline at the intersection of design, planning, and GIS/IT. The SDS Knowledge Portal provides DoD researchers and decision makers with access to the relevant information and resources for solving specific problems. The Portal can help DoD users to 1) gain a systematic understanding of the planning and decision making process; 2) select appropriate workflow templates, methods, tools and models, data sources, literature and other useful resources for a specific problem type; and 3) learn about relevant case studies with project needs similar to theirs.

The SDS Workshop was greatly enhanced by the participation of several members of the SDS Consortium. As can be seen in the notes below, SDS Consortium members are conducting research and sharing their knowledge. This is a valuable resource for the DoD research community.

Participants

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* *indicates members of the Spatial Decision Support Consortium*

Presentations

Presenter	Title
Bill Goran, ERDC-CERL	Historical and Current GIS/SDS Work at CERL
Jordan Henk, Redlands	University of Redlands SDS Research
Arika Ligmann-Zielinska, Michigan State University **Piotr Jankowski, San Diego State University**	Spatial Sensitivity Analysis: An Overview
David Krooks, ERDC-CERL	Overview of CREATE Project: Cultural Reasoning and Ethnographic Analysis for the Tactical Environment
George Calfus, University of Illinois and ERDC-CERL	Light Detection and Ranging (LiDAR): Uses in Land and Heritage Management
Jeff Hamerlinck, Wyoming Geographic Information Science Center	Decision Support System Adoption and Use Issues
Matthew Hohmann, ERDC-CERL	Prioritization of NISM on DoD installations
Sean Gordon, Oregon State University	SDS Research and Project Overview: 1. NW Forest Plan Watershed condition 2. WA DNR spotted owl dispersal habitat 3. Integrated Landscape Assessment Project 4. Sociology of DSS (case studies)

Elements of an SDS Research Agenda

Following the presentations, the workshop participants identified a set of topics that emerged as potential elements in a future collaborative research agenda:

1. **Theory, Methods, and Best Practice**
    a. **Principles and Factors for System Adoption and Effectiveness**. This topic was identified in the presentations by Hamerlinck and Gordon. The hypothesis of this theme is that SDS systems would be better designed, adopted, and applied with improved knowledge of the factors contributing to robust implementations.
    b. **Science-Policy Integration**. This core theme refers to the need to improve the integration of scientific knowledge into the policy decision making process, and conversely, the need to have management decision-making requirements inform the scope and nature of future scientific research activities.
    c. **Strategic Prioritization vs. Tactical Implementation**. Reynolds and Murphy called for more work to distinguish the appropriate scope of decision support applications. Some systems provide support at the strategic level, by assessing 'landscape' condition as the basis for prioritizing areas for management, but without specifying treatment locations or types. Other systems may go further, to the tactical level, and suggest specific management actions or implementations.
    d. **Role of Experts; Institutionalization of Expertise**. This topic was identified by several agency representatives. The issue includes research on how to codify expert knowledge so that it may be accessed in the design and development of SDS systems.
    e. **Model-Driven Data Acquisition**. This topic was raised by Reynolds and Krooks. There is a need to have system design start with the development of conceptual models to avoid expensive data collections and information overload. Participants shared examples of systems development that focused initially on data gathering, which often led to an investment of considerable time and funding on non-essential data.
    f. **Advances in Coupling the Temporal and Spatial Dimension**. Goran noted the need to improve representations that integrate temporal and spatial analysis. There has been a positive evolution of spatial technologies, but we still need more powerful tools to integrate temporal representations in decision analysis.
    g. **Multi-Scale / Cross-Scale Analysis**. Reynolds and Murphy outlined a recurring need for effective systems to be capable of modeling across multiple spatial and temporal scales of analysis.
    h. **Sensitivity Analysis to Improve Model Quality**. Ligmann-Zielinska, Jankowski, and Murphy identified the need for more robust sensitivity methods to ensure the validity of model construction, and to improve our representation and management of uncertainty and error. In particular, they stressed the importance of spatial approaches to sensitivity analysis which identify areas of high output uncertainty and therefore allow for efficient allocation of resources for future data collection, model improvement, and outcome credibility.

i. **Geovisualization / Geosimulation**. There is an ongoing need to define effective visualizations and simulations as methods for representing complex system processes within the decision context. This is especially critical in the area of prediction and forecasting in global and regional systems.

j. **Method/Model/Decision Transparency**. Several project case studies emphasized the need for modeling environments that transform 'black boxes' into transparent decision support systems.

k. **Adaptive Management**. Participants recognized the need for research on applying adaptive management techniques to improve SDS design and development. This focus is in addition to the more common objective of using SDS tools to foster adaptive management within specific domain application areas such as natural resource management.

2. Technologies. Several technological research topics were identified:

a. **Dashboards**. Literature and practice are regularly calling for the creation of unified system visualization interfaces, or dashboards. These interfaces may display the state of the decision support system (model management and control), or they may display the state of the subject (landscape, or ecosystem condition, for example).

b. **Model Controllers**. Hohmann, Ong, Li and Murphy demonstrated the need for analytical management tools that assist domain experts in decomposing complex systems into more finite arrangements of relationships for which expert process knowledge may be more easily codified as smaller modeling constructs.

3. **Domain Application Areas**. Participants recognized the need to further SDS research in several core domain areas:

a. **Planning/GeoDesign**. SDS has significant potential to improve common planning-related tasks in Natural Resource Management. SDS applications for non-native invasive species are a prominent area of need. GeoDesign technology that delivers immediate feedback to designers was recognized as an emerging domain area for SDS research and development. SDS for planning, design and assessment of sustainability is an emerging application area that requires better tools for performing trade off analyses, and better representation for assessing relationships among vulnerability, risk, and resilience.

b. **Socio-Cultural / Human Terrain Modeling**. The DoD has an immediate need for SDS applications solidly grounded in the social sciences that can improve the quality of cultural reasoning and ethnographic analysis of dynamic human systems The objective is to improve the quality of pre-intervention intelligence. Krooks noted the need to construct robust conceptual models as the basis for analytical processing. This research area includes the need for better tools to perform media content analysis, motive-opportunity structural analysis, handling individual vs. group analysis, and remote decision analysis.

4. **Standardization**
    a. **OGC**. Goran recommended collaboration with the Open Geospatial Consortium (OGC) to explore development of standards for SDS. There is an OGC Domain Working Group (DWG) that is working on decision support[2].
    b. **Ontological Knowledge Codification; Ontological Reasoning Applications**. Members of the SDS Consortium expressed the need to strengthen the knowledgebase of the SDS Knowledge Repository. There is also a need to build reasoning applications to access the breadth and depth of SDS knowledge encoded in the ontologies for specific end-user applications. One such application envisioned would assist users in identifying SDS workflows, methods and tools for implementing specific kinds of decision processes.
    c. **Interoperability**. This topic has two dimensions: 1) ontological structures that codify attributes of methods/tools to enable interoperability, and 2) the development of applications, such as wrappers and translators, which would aid in the implementation of systems by providing the ability to connect previously non-interoperable components.
5. **Education and Training**. Miller identified a potentially pervasive disconnect in natural resource education and training. He suggested a theme of research toward development of a suite of SDS learning modules that could be targeted as professional development for a broad range of natural resource staff positions (biologists, ecologists, land managers, etc.). The workshop participants all acknowledged a need to prepare and deliver fundamental courses, seminars and training on the topic of SDS. High priority target recipients include DoD decision makers in natural resources, management, and planning. A rough curriculum could include fundamental modules in spatial literacy, decision support systems, and common decision frameworks (processes, methods, and tools). Training in this case refers to general education on a technical topic, but does not refer to software training on a particular tool or technology. Gordon emphasized the need to include relevant case studies in the educational curriculum as a means of sharing and institutionalizing a collective case memory.

[2] The Decision Support DWG discusses requirements for interfaces necessary for interoperable service chaining (common expression and execution) in the areas of data mining, Integrated Client to access all OWS services and simulation. The DS DWG is currently reworking its mission to better reflect current OGC and IT best practices with regard to decision support. Chair: Stan Tillman, Intergraph. Vice Chair: Ian Turton, Penn State.

Action Items

The workshop participants identified several action items:

1. Prepare a Technical Report for ARO and ERDC (this document).
2. Prepare and arrange to present a summary of SDS research process to other DoD laboratories. Redlands will coordinate with CERL and ARO to offer briefings at other ERDC labs as requested. This information may be particularly relevant to research in progress at CRREL, AGC, IWR, ER, and ITL.
3. Redlands will provide an update to the full SDS Consortium, and make a call for interest in collaborative research on the topics identified.
4. Redlands will develop a series of short learning modules that can be delivered as part of an extended briefing session, or training session if requested by any of the DoD laboratories.
5. Redlands will coordinate efforts toward the preparation of a new, joint grant proposal with DoD researchers who express interest in specific areas of collaborative research.

Author Comments

Due to travel restrictions in effect at the time of the workshop, some would-be participants from other ERDC laboratories, installations, and districts were unable to attend. We believe that more outreach should be undertaken. Given the significant investment made by ARO, and to best meet the objectives of W911NF-07-1-0392 - *GIS Program Initiative to Enhance Knowledge, Skills and Technology for DoD Research Facilities*, Redlands believes the best application of our remaining time and grant funding is to focus on SDS research technology transfer and educational outreach to the DoD. We believe that SDS has broad applicability to multiple DoD user communities, and that it has transformative potential for both civilian and military operations in the DoD. We would welcome the opportunity to meet with DoD leadership to refine our outreach agenda so that it best informs planning toward future collaborative research.

Contact Information

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